11 PRT

10/529626

JC13 Rec'd PCT/PTO 30 MAR 2005

Description

OPTOELECTRONIC COMPONENT AND A MODULE BASED THEREON

The present invention relates to an optoelectronic component in accordance with the precharacterizing part of patent claim 1 and to a component-based module in accordance with the precharacterizing part of claim 17.

Radiation-emitting semiconductor components can be arranged in a matrix in order to attain a high-intensity overall module.

An arrangement of this type, referred to as an LED module, is known from DE 10051159 A1. In this case, a plurality of optoelectronic semiconductor arrangements or semiconductor chips are mounted on a carrier which is in turn arranged on a heat sink. Despite the increasing packing density of the semiconductor components, it is possible to dissipate the heat produced. In this case, the heat produced must not affect the electrical behavior of the semiconductor component, however, or must affect it only insignificantly. This practice reduces the efficiency of the overall module on account of the absorption of the radiation from adjacent semiconductor components, however.

By placing the individual radiation-emitting semiconductor components in a reflector, it is possible to improve the module's radiation and directional characteristics, since at least some of the radiation emitted at the side of the individual semiconductor components is reflected into the primary radiation direction.

A module with a high level of efficiency and very good directional characteristics can be assembled from

individual semiconductor components which are each situated in an individual reflector. In this context, however, it is difficult to obtain a high packing density for the semiconductor components together with the reflector in the overall module. The contact-connections between the semiconductor components stand in the way of flexible connection and a high packing density.

The present invention is therefore based on the object of providing an optoelectronic component and a component-based module which allow adjacent semiconductor components or optoelectronic semiconductor arrangements to be in close arrangement.

In particular, the object is based on providing a semiconductor component having a contact-connection arrangement which allows the conduction of heat to be isolated from the conduction of electricity.

This object is achieved by means of the features of claims 1 and 17. Further features of advantageous refinements and developments of the optoelectronic component are specified in the dependent claims 2 to 16 and 18.

The invention provides an optoelectronic component having a semiconductor arrangement which emits and/or receives electromagnetic radiation and which is arranged on a carrier which is thermally conductively connected to a heat sink. Bonding wires connect the external electrical connections to the connections of the semiconductor arrangement. The external electrical connections are arranged in electrically insulated fashion on the heat sink at a distance from the carrier.

This has the advantage that the electrical conductive connections are largely decoupled from the conduction

of heat. The thermal connection of a semiconductor arrangement or chip on the heat sink by means of the carrier allows a large number of chips to be arranged closely on the heat sink and allows the heat to be dissipated. The electrical contact-connection between the chips can be made flexibly using the connections insulated from the heat sink. In addition, compact reflective housings can be fitted on the external electrical connections, which reduces the space requirement for the component and allows high luminous efficiency.

This practice has the advantage that the flow of electric current does not pass through the heat sink, which dissipates the heat produced during operation of the semiconductor component.

It is advantageous if the carrier includes a carrier substrate and at least one electrically insulating layer arranged thereon. Alternatively, the carrier material itself is an electrical insulation. In that case, the semiconductor arrangement does not need to be insulated from the carrier separately and may be arranged on a conductive substrate without producing a short circuit between them or with the heat sink.

The semiconductor arrangement and the electrically insulating layer may have an electrically conductive layer arranged between them which is connected to an external electrical connection. This is expedient particularly for a semiconductor arrangement on a conductive substrate, because it is possible to route a connection for the semiconductor arrangement by means of a bonding wire via the electrically conductive layer.

It is particularly advantageous if the external electrical connections include conductor tracks on a printed circuit board. The printed circuit board

contains an insulating substrate with a conductor track and can therefore be mounted directly on the heat sink. It is also possible for a plurality of printed circuit boards to be arranged above one another, these then also being insulated from one another.

Conductor tracks which can be connected to one another by means of plated-through holes on different printed circuit boards arranged above one another further increase the flexibility of the connection of a large number of optoelectronic components.

Provision is advantageously made for the carrier substrate to have at least one material with good thermal conductivity from the group comprising Si, diamond-coated Si, diamond, SiC, AlN and BN.

It is also advantageous if the electrically insulating layer comprises SiO_2. This is particularly advantageously the case when the carrier layer comprises silicon.

In a large number of components, these materials used in semiconductor technology reduce the strain among one another and with respect to the semiconductor chips themselves.

In one advantageous embodiment, the semiconductor arrangement is attached to the carrier by means of a metal solder or a thermally and/or electrically conductive adhesive.

Good thermal conduction or dissipation of heat is obtained if the carrier is attached to the heat sink by means of a metal solder or a thermally conductive adhesive.

Very good radiation of light becomes possible if the semiconductor arrangement and the carrier are arranged in a basic housing which has reflective properties.

The radiation of light can be adapted to the chip very well and individually if the basic housing contains precisely one semiconductor arrangement. In that case, the light efficiency of the semiconductor component does not decrease on account of absorption of an adjacent semiconductor arrangement within the cavity.

The optoelectronic component based on the invention has a cavity or cutout in the basic housing which (cavity or cutout) contains the semiconductor arrangement which emits and/or receives electromagnetic radiation. Unlike in conventional optoelectronic components, the reflector is at least produced not just by reflective lateral faces of the cavity in the basic housing itself, but rather at least partly by a reflective filling compound which the cavity contains. For this, the material and the quantity of filling compound are chosen such that, during and/or after filling, the adhesive force between the material of the filling compound and the material of the lateral faces of the cavity causes the filling compound to rise up on these lateral faces and form a parabola-shaped surface. This filling compound surface facing the front of the housing serves as a reflective area for electromagnetic radiation emitted and/or received by the semiconductor arrangement.

In other words, the cavity is partly filled with the filling compound, and the adhesive force between the filling compound and the basic housing causes the filling compound to form a concave surface in the cavity automatically, since the filling compound rises up on the lateral internal faces of the cavity of the basic housing. The filling compound's parabolic

internal faces formed in this manner form the reflector for the semiconductor arrangement inserted into the cavity.

Even with very small openings in the cavities, these reflective areas can easily be produced in the cavity through suitable dosage of the filling compound. As a result, the lateral walls of the housing and the filling compound behave like a single reflector, which further improves the light radiation power. In addition, the conductor tracks, wires and the like which the cavity contains are enveloped by the filling compound without impairing the manner of operation thereof.

Hence, even in the case of optoelectronic components with narrow openings in the cavity and/or complex semiconductor arrangement and wiring arrangements in the cavity, the inventive measure can be used to provide reflectors within the cavity and hence to increase the light efficiency of the components.

It is particularly advantageous if the basic housing is formed at an angle on the inner side which faces the semiconductor arrangement, so that the basic housing has a reflective area for a portion of the radiation emitted by the semiconductor arrangement.

The filling compound provided is preferably TiO_2, or an epoxy resin filled with TiO_2 particles, or silicone.

In addition, the cavity of the housing is at least partly filled with a radiation-pervious encapsulation compound. This firstly makes it possible to protect the chip and its connections. In addition, with appropriate choice of chip and of encapsulation compound, it is possible to produce components in different colors. By way of example, white-radiating components using a GaN-

based chip and an encapsulation compound which contains YAG:Ce particles.

This encapsulation compound may advantageously contain epoxy resin or silicone. When using silicone, mechanical stresses in the semiconductor component or in a module comprising individual semiconductor components can be reduced to a high extent.
Preferably, at least some of the external connections are arranged between the basic housing and the heat sink. This allows the optoelectronic components to be connected in a particularly space-saving manner.

Preferably, the invention uses high-power chips as semiconductor arrangement. In this context, the component is provided for an electrical power consumption of at least 0.5 W. In a further advantageous variant, the component is provided for an electrical power consumption of at least 1 W. In a particularly advantageous variant, the component is provided for an electrical power consumption of at least 3 W.

On account of the conduction of heat and electricity being decoupled, the invention also requires an advantageously small amount of space, with the base area of the component preferably being less than or equal to 1 cm^2, even when high-power chips are used.

With particular advantage, the scope of the invention allows the plurality of inventive optoelectronic components to be arranged to form a module. In a module of this type, the optoelectronic components are preferably arranged in the form of a matrix and at least some of them are connected in series.

For a plurality of optoelectronic components, a respective basic housing is provided in this case.

In one particularly preferred embodiment of the invention, the carrier's topmost layer facing the semiconductor arrangement is electrically conductive. Preferably, this electrically conductive layer essentially comprises a metal.

At least some of the optoelectronic components are preferably electrically conductively connected to one another by conductor tracks, some of which may be arranged between the basic housing and the heat sink, in particular. The conductor tracks for connecting the semiconductor chips allow the optoelectronic components to be connected to an adjacent component in a highly space-saving manner. No bonding wire is routed via the edge of the basic housing. The conductor tracks allow components to be connected in complex fashion. The conductor tracks may be situated in a printed circuit board (e.g. FR4, flexible printed circuit board) which has appropriate cutouts. The printed circuit board may be in multilayer form, which means that in addition to conductor tracks further functional elements may be present in a multilayer structure.

Further advantages and advantageous developments of the inventive optoelectronic component can be found in the exemplary embodiments described below in conjunction with the figure.

The figure shows a schematic illustration of a sectional view of the exemplary embodiment.

In the case of the optoelectronic component 1 shown in the figure, a semiconductor arrangement 4 emitting and/or receiving electromagnetic radiation is arranged on a carrier 22. The carrier 22 is thermally conductively connected to a heat sink 12 made of copper, aluminum or molybdenum, for example. External electrical connections 9 are electrically connected to the semiconductor arrangement 4 or to an electrically

conductive layer 13 via bonding wires 7. The electrically conductive layer 13 makes contact with the underside of the semiconductor arrangement 4, which is constructed such that a current can flow vertically through the arrangement, e.g. by virtue of the substrate being conducted for the active layer which produces the light.

In another embodiment with an insulating substrate for the active layer, the second bonding wire is likewise routed to the semiconductor chip directly.

In the figure, the electrically conductive layer 13 is insulated from the carrier substrate 2 of the carrier 22 by means of an electrically insulating layer 14. The electrically insulating layer 14 may preferably have two layers and be made of silicon oxide and a passivation layer applied above that, e.g. made of silicon nitride, which electrically isolates the carrier substrate, which has good thermal conductivity and is preferably made of silicon or of gallium arsenide, from the electrically conductive layer 13. Ceramic-type materials with good thermal conductivity, such as aluminum nitride or boron nitride or carbides, are also suitable as carrier substrate. The carrier 22 is mounted directly on a heat sink 12 made of aluminum, copper or molybdenum by means of a solder connection or an adhesive bond. With an electrical power consumption by the component of at least 0.5 W and a base area for the component of no more than 1 cm^2, the heat produced can be effectively dissipated from the component when the flows of heat and current are isolated as described. In another embodiment, a power consumption by the component of at least 1 W or even at least 3 W is provided.

Likewise directly on the heat sink 12, external electrical connections 9 are arranged in electrically insulated fashion and at a distance from the carrier

22. The external electrical connections 9 are preferably conductor tracks from printed circuit boards 10 which are arranged above one another and which form the connection arrangement 8. The two chip connections require at least one printed circuit board. A plurality of chips in a module are preferably connected by multilayer printed circuit boards which allow flexible connection, for example series connection of components arranged in the form of a matrix. Different conductor tracks on various printed circuit boards are connected by means of plated-through holes respectively between the basic housing 20 and the heat sink 12 of an optoelectronic component.

The semiconductor arrangement 4 with the carrier 22 is situated in a basic housing 20 with a cutout or cavity 3. The basic housing may be a frame which is mounted on the printed circuit boards 8 with the electrical connections 9. This allows a very compact design for the inventive component 1. This also allows the inner side 17 of the basic housing 20 to be in the form of a reflector 30 in order to output as much and as directional light as possible from the component.

The semiconductor chip 4 and the lateral walls 17 of the cavity 3 have a filling between them which comprises a reflective filling compound 16 which, by way of example, is made of epoxy resin filled with TiO_2 particles, the proportion of TiO_2 in the filling compound 16 being sufficient to increase the reflective power of the filling compound to a significant extent. The filling compound extends on the chip side to approximately the top edge of the carrier 22. Preferably, the proportion of TiO_2 in the filling compound 16 is between approximately 10 and 50% by volume. Particles comprising zirconium dioxide, zinc oxide, barium sulfate, gallium nitride, aluminum oxide or a mixture of at least two of these are also suitable for use with an epoxy resin in the filling compound 16.

What is important is that the difference in reflective index between the epoxy resin and the particles is sufficiently great for the reflectivity of the filling compound to rise.

As seen from the semiconductor chip 4, the filling compound surface which faces the front 21 of the basic housing 20 is convex and forms a reflective area at least for a portion of the radiation emitted and/or received at the side.

The free surface region of the semiconductor chip 4 which is situated above the filling compound is covered by a radiation-pervious encapsulation compound 6 and, by way of example, is in turn made of an epoxy resin or other suitable reaction resin.

As can be seen in the sectional view of the figure, the filling level of the filling compound 16 is low adjacent to the semiconductor chip 4, i.e. adjacent to the carrier 22. This means that the shape of the surface of the filling compound 16 opens essentially parabolically toward the front in conjunction with the surface 30 of the lateral wall of the housing 20. With a suitable choice of material and of dosage for the filling compound, this shape is obtained automatically on account of the adhesive forces between the filling compound and the material of the housing frame 20. The concave inner faces of the filling compound 16 (as seen from the semiconductor chips 4) serve as reflector for the radiation which is emitted and/or received by the semiconductor chips 4 at the side.

The reflective power of the filling compound 16 with the TiO_2 proportion it contains is up to approximately 80%. In comparison with an optoelectronic component in which the cavity is filled exclusively with a transparent filling compound, the optoelectronic

component 1 of the present invention was able to be used to increase the external efficiency considerably.

To protect the semiconductor chips 4, the cavity 3 is filled entirely with a radiation-pervious, for example transparent, encapsulation compound 6 which envelops the semiconductor chip 4 and which is pervious to radiation for emission or reception by the semiconductor chips 4. As in the conventional components, suitable filling compounds made of transparent artificial resins, such as epoxy resin, or made of polycarbonate may be used for this encapsulation compound 6, which is preferably particularly in tune with the properties of the filling compound.

The above description of the invention using the exemplary embodiment is naturally not to be understood to mean a restriction of the invention thereto. Rather, the inventive concept set out in claims 1 and 25 can be applied for a large number of very different designs. In particular, the invention also covers all combinations of the features cited in the exemplary embodiments and in the rest of the description, even if these combinations are not the subject matter of a patent claim. The content of that application whose priority is claimed is incorporated into the present description by reference.